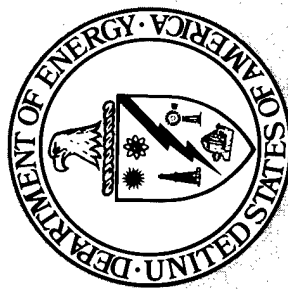


19980513 172

# A Facsimile Report



Reproduced by

**UNITED STATES  
DEPARTMENT OF ENERGY**

Office of Scientific and Technical Information

Post Office Box 62

Oak Ridge, Tennessee 37831



PLEASE RETURN TO:

BMD TECHNICAL INFORMATION CENTER  
BALLISTIC MISSILE DEFENSE ORGANIZATION  
7100 DEFENSE PENTAGON  
WASHINGTON D.C. 20301-7100

DTIC QUALITY INSPECTED 4

U2904

Accession Number: 2904

Publication Date: Jan 01, 1990

Title: Multiple Target Tracking in a Wide-field-of-view Camera System (Paper)

Personal Author: Park, H-S.; Axelrod, T.S.; Colella, N.J.; et al.

Corporate Author Or Publisher: Lawrence Livermore National Laboratory, Livermore, CA 94550 Report Number: UCRL-101921

Descriptors, Keywords: SDI Target Track Camera VLSI Transputer

Pages: 00007

Cataloged Date: May 10, 1991

Document Type: HC

Number of Copies In Library: 000001

Original Source Number: DE90-013488

Record ID: 21990

Source of Document: NTIS

# Multiple Target Tracking in a Wide-Field-of-View Camera System\*

Hye-Sook Park, Timothy S. Axelrod, Nicholas J. Colella,  
Michael E. Colvin, and Arno G. Ledebuhr

Lawrence Livermore National Laboratory  
P.O. Box 808  
Livermore, California 94550

UCRL--101921

DE90 013488

## 1. INTRODUCTION

We are developing a real-time-multiple-target-tracking system using a wide-field-of-view (WFOV) camera. The high resolution WFOV camera was conceived as part of the Strategic Defense Initiative Research at Lawrence Livermore National Laboratory. The camera system consists of a lens made of concentric solid blocks of index matching glasses, CCDs arrayed on the focal plane, and a custom VLSI image processor to extract the targets. References 1 and 2 describe the basic design of the WFOV camera and the prototype system that we have constructed. In this paper, we will briefly review the existing prototype system, the on-going effort to cover the full field of view using digital CCD cameras, the production of custom VLSI chips developed to extract centroids in real time, and the implementation of transputers to run the tracking algorithms.

## 2. PROTOTYPE MULTI TARGET TRACKING SYSTEM

The prototype system was constructed in an attempt to study the properties of the high resolution WFOV lens and its target tracking algorithms. The f/2.8 lens was constructed by Perkin Elmer, has an aperture of 89 mm, and a focal length of 250 mm. The spot size over the wavelengths of 600 ~ 670 nm is 4.3  $\mu\text{m}$  in diameter and the measured transmitted wavefront error is < 0.065 waves across the entire field-of-view (FOV) at 632.8 nm.

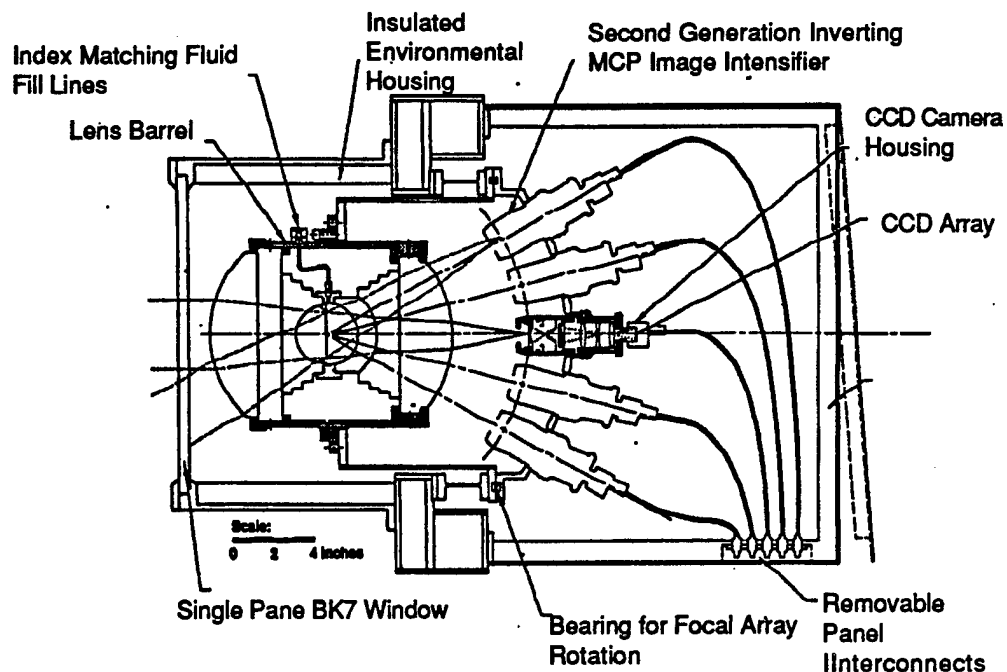
Five commercial intensified CCD cameras (Pulnix 840) on the focal plane output RS170 video signals which are fed into a Datacube image processor where real time tracking algorithms are implemented. Figure 1 shows the schematic of the cameras and the lens assembly within an environment chamber that maintains a constant temperature of 70°F  $\pm$  1°. This assembly is mounted on a Contraves alt-azi axis table with a pointing accuracy of < 2  $\mu\text{rad}$ .

---

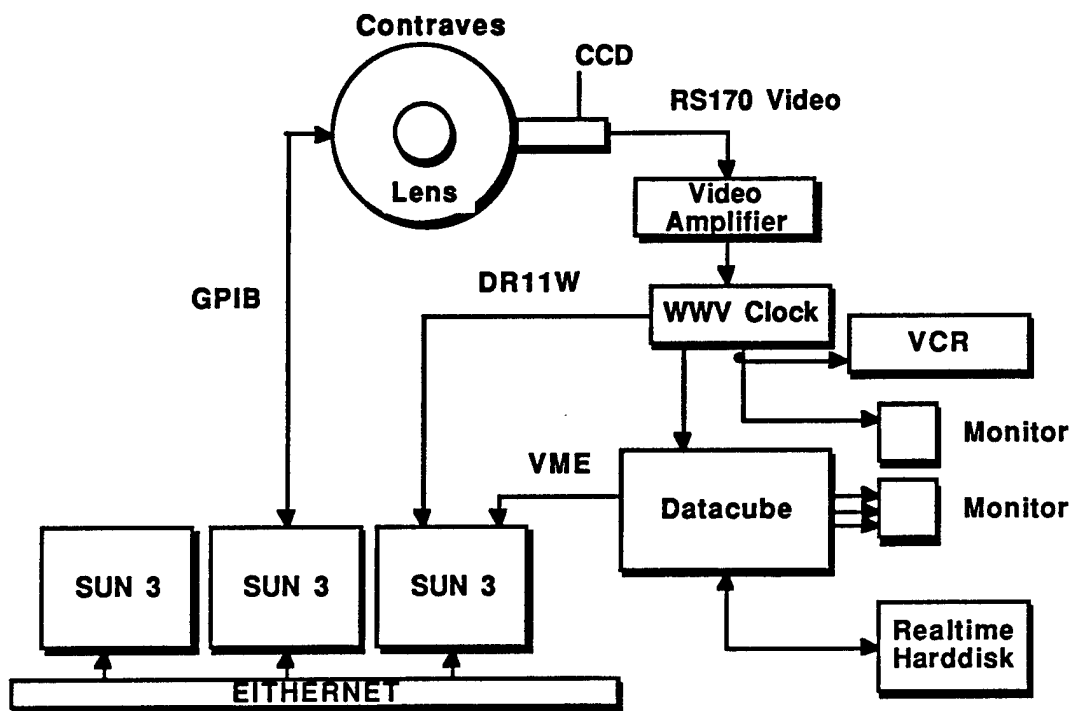
\* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED



**Figure 1:** Wide-Field-of-View lens and five camera assembly for the prototype tracking system. The system is mounted on alt-azi indexing table; and tracks low earth orbiting satellites.



**Figure 2:** Data Acquisition for the prototype WFOV tracking system.

The data acquisition system for this prototype system is shown in Fig. 2. The camera output signals are amplified before and after they travel ~100 meter of cable to reach the indoor signal processing laboratory. Each incoming image is annotated with WWV timing.

We use Datacube boards to perform general image processing on our images. Its modularity and open architecture make it easy to implement our algorithms to see their real time performance. The image processor boards are used to digitize the images, to average many frames, to create real time histograms, to extract features and blobs, and to write images to disk in real time. The Datacube is controlled by a SUN 3 via VME bus. We use at least 2 monitors: one for displaying the live image signal directly from the cameras and the other for displaying processed images with overlay from the Datacube.

We control the Contraves table using a GPIB interface on the SUN. GPIB also interfaces a CAMAC crate that controls the camera on/off switches and the focusing motors. An X window display system is utilized to pass data between SUNs using Remote Procedure Calls (RPC).

We view the night sky mainly to track low earth orbiting satellites. Details of the tracking algorithms are explained in Reference 2. In this experiment stars are stationary over a few seconds, and the satellites appear as a star like objects moving through the field of view. The goal of the tracking algorithm is to recognize the entrance of any moving targets into the field of view; to track them while predicting their position and velocity using a Kalman Filter; and to recognize their disappearance from the field of view.

In order to subtract stationary objects and account for the inhomogeneous sensitivity of the focal plane array, we subtract a background image from the incoming live image. The background image is obtained by averaging many frames.

The background subtracted image is fed into a blob analyzer board which finds blobs in real time. The blobs are defined to be connected pixels above a specified threshold. The threshold is determined by looking at the mean and sigma of the real time histogram. The threshold is defined as:

$$\text{Threshold} = \text{mean} + \chi \times \text{sigma}$$

where  $\chi$  is set by the user. The list of blobs are compared with an internal track list. If any track finds a blob within its gate, it updates the tracking information using a Kalman Filter described in Reference 3 and forms a new gate. The blobs which do not belong to any existing tracks are listed as candidate tracks. If any candidate tracks are updated more than 5 times consecutively, they are registered as real tracks. This intermediate track registration method eliminates spurious triggers from noise hits.

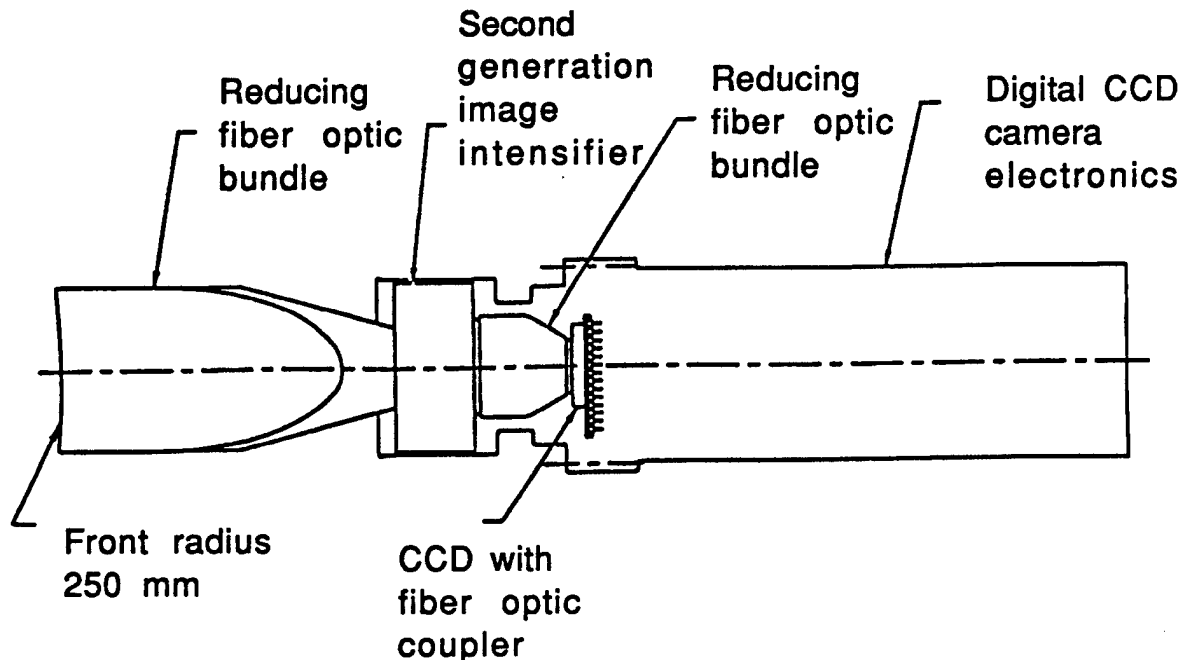
When a track is not updated in 300 msec, it is tagged as disappearing from the FOV. The program dumps the tracking information into a file for later analysis and frees the memory.

The background image and the threshold are constantly updated to take into account the background sky light level changes caused by the moon or clouds etc. The resolution of our tracking is 0.5 ~ 1.0 pixel and is limited by the accuracy of the blob analysis board which operates on binary images.

### 3. FULL FIELD OF VIEW UPGRADE CAMERA ASSEMBLY

We are upgrading the focal plane to cover 75% of the FOV. The new focal surface assembly will be covered with  $5 \times 10^6$  pixels using 23 custom digital cameras, 23 custom VLSI chips, and 23 custom processing boards.

A schematic of camera assembly is shown in Fig. 3. In order to cover the large field of view, we use fiber optic reducers that demagnify the image by a 3.8:1 ratio. The front surface of the fiber bundle is machined to match the spherical focal plane (curvature radius 250 mm). The back end of the fiber optic reducer is glued to an image intensifier. The photo output of the intensifier goes through a second reducing fiber optic bundle glued onto a CCD array. We use Thompson TH 7882 CCDs which have  $384 \times 576$  pixels that are  $23 \mu\text{m} \times 23 \mu\text{m}$  across.



**Figure 3:** Camera and reducing optical fiber bundle assembly. There are 23 of these cameras to cover 75% of the field of view. The cameras output digital pixel values at 7 MHz rate. The images are analyzed by 23 custom image processing VLSI chips and transputers.

We designed custom readout electronics circuitry for these CCDs. The basic clock rate is 7 MHz and the electronics will output individual pixel values digitally. The gain of the intensifier can be adjusted by a potentiometer which is computer controlled by CAMAC interface. The integration time of the CCD and intensifier is controlled by thumb wheel switches independently and synchronized for all 23 cameras.

#### 4. AUTOMATIC CENTROID EXTRACTOR

The output of each camera is fed into a custom automatic centroid extractor (ACE) which finds the blobs in the incoming image in real time. We are developing a VLSI chip and a printed circuit board that perform the connectivity analysis of the convex groups of pixels above a specified threshold.

The ACE will output SUMXI (sum of X position of the blob weighted by gray value of the pixel); SUMYI (sum of Y position weighted by gray value); SUMI (sum of the gray value of the pixels in the blob); and SUMN (number of pixels in the blob). Then, the centroid is  $X_c = \text{SUMXI} / \text{SUMI}$ ;  $Y_c = \text{SUMYI} / \text{SUMI}$ . With the gray value weighted sums, the centroid accuracy is expected to be  $\sim 0.1$  pixels.

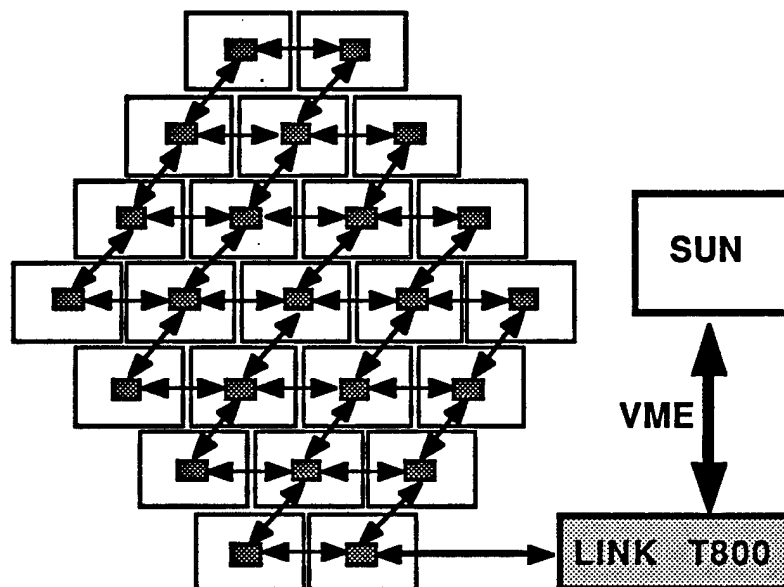
The ACE also has 1 MBit of RAM (1bit / pixel) to mask out unwanted pixels. By locating the star positions and sizes accurately, we can mask out those areas and exclude from further analysis. Although the Thomson CCD is only  $384 \times 576$  pixels we allocated 1 MBit in order to use the ACEs for any digital cameras up to  $1K \times 1K$  size.

The printed circuit version of the ACE electronics has a 1 KByte RAM to store the resulting blob information which limits it to 500 blobs / frame. However the VLSI chip version utilizes a FIFO memory so that it can analyze an unlimited number of blobs in the image (providing that the readout speed is faster than the connectivity analysis). The current ACE chip design consumes 0.5 watts. More detailed design specifications for the ACE chip and the PC board are described in Reference 4.

## 5. TRANSPUTER

The ACE blobs result is transferred to 23 Inmos T800 transputers running the tracking algorithms. Their main functions are to control the ACE registers and to perform multiple target tracking algorithms. We chose the transputers because of their capability to link to neighboring transputers. Figure 4 shows the map of the network connection of transputers for our 23 camera system. In this multi processor environment, when a track is leaving the field of view, the transputer sends its target position, velocity, and gate to the adjoining transputer which continues tracking the target.

The individual transputer interface board contains 8 MBytes of RAM memory to load user programs. The transputers latch WWV time by the frame valid signal from the camera.



**Figure 4:** The map of the network connection for 23 camera system. Each rectangle represents one camera assembly. The arrowed lines represent the transputer link to the neighboring ones. When a track is leaving the field of view, the transputer sends its tracking information to the adjoining transputer which continues tracking the target.

## 6. DATA DISTRIBUTION

The data distribution for this system is diagrammed in Fig. 5. At the data distribution station the camera output is divided into 3 paths: one to the ACE for blob analysis; one to our custom RS170 generator to display the image on a monitor; and the other to the Datacube. The Datacube is used to perform general image processing on the digital images including determination of the threshold, control of overlays, and finding stars in the image. We overlay a 1 bit plane over the RS170 display to draw cursors so we can see the performance of the tracking in real time.

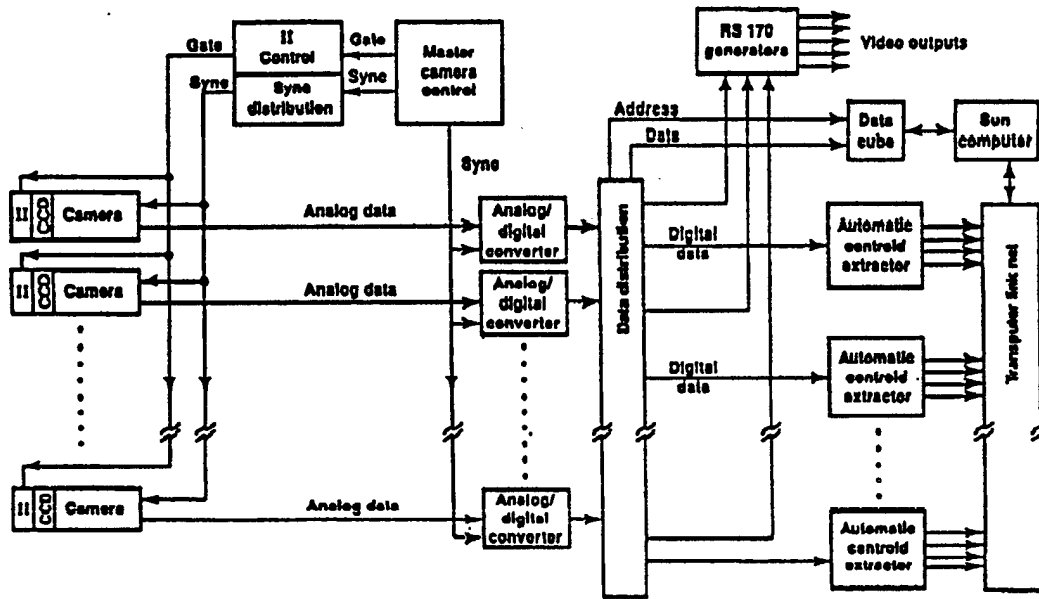


Figure 5: The data distribution diagram for the full field of view upgrade.

## 7. CONCLUSION

Currently, we completed the testing of prototypes of the camera electronics, the ACE board, and the transputer interface board. We have now started the production of the 23 units. We have successfully run the tracking algorithm across 3 nodes on simulated tracks. We anticipate that the complete system will be up and running by the summer of 1990.

In conclusion, we have demonstrated the capabilities of the WFOV camera lens. We have developed a real time multiple target tracking algorithm for processing the signal from this WFOV camera system. We are developing a full field of view system with  $> 5 \times 10^6$  pixel elements using custom VLSI chips and a highly parallel image processing architecture which we will use to construct a high quality database for low earth orbit satellites.

We wish to acknowledge the contributions of the technical staff of the WFOV telescope project including R. Allen, T. Boyd, W. Davis, J. Dickie, F. Eechman, J. Ewins, D. Gustaveson, T. Hindley, T. Letendre, B. Lopossa, M. Mercer, J. Noonan, T. Tassinari, D. Williams.



## **8. REFERENCES**

1. "Wide-Field-of-View Camera", *Energy and Technology Review* from Lawrence Livermore National Laboratory, UCRL-5200-88-12, December (1988).
2. H.S. Park et. al., "Realtime Tracking System for the Wide-Field-of-View Telescope Project", in *Acquisition, Tracking, and Pointing III*, S. Gowrinathan, editor, SPIE, 1111, 196 (1989).
3. Bernard Friedland, "Optimum Steady-State Position and Velocity Estimation Using Noisy Sampled Position Data", *IEEE Transaction on Aerospace and Electronic Systems*, AES-9, No. 6, 906 (1973).
4. T.S. Axelrod and T.F. Tassinari, "A VLSI Centroid Extractor for Real-Time Target Tracking Applications", in *Real-Time Signal Processing XII*, J. P. Letellier, editor, SPIE, 1154, 306 (1989).